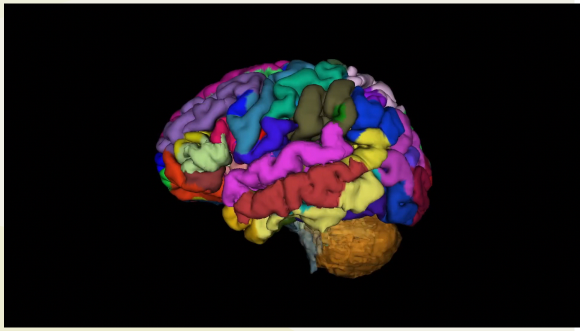
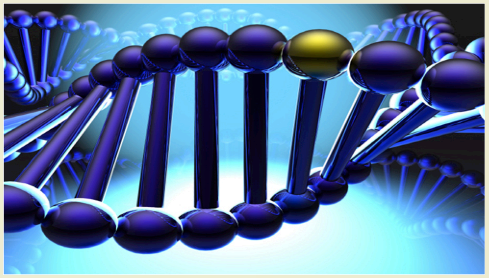
USING MEG TO UNDERSTAND BRAIN MECHANISMS UNDERLYING LANGUAGE ACQUISITION IN INFANTS

Patricia Kuhl, Ph.D.
Co-Director, Institute for Learning & Brain Sciences
Bezos Family Foundation Endowed Chair in Early Learning
University of Washington, Seattle

Brain Function

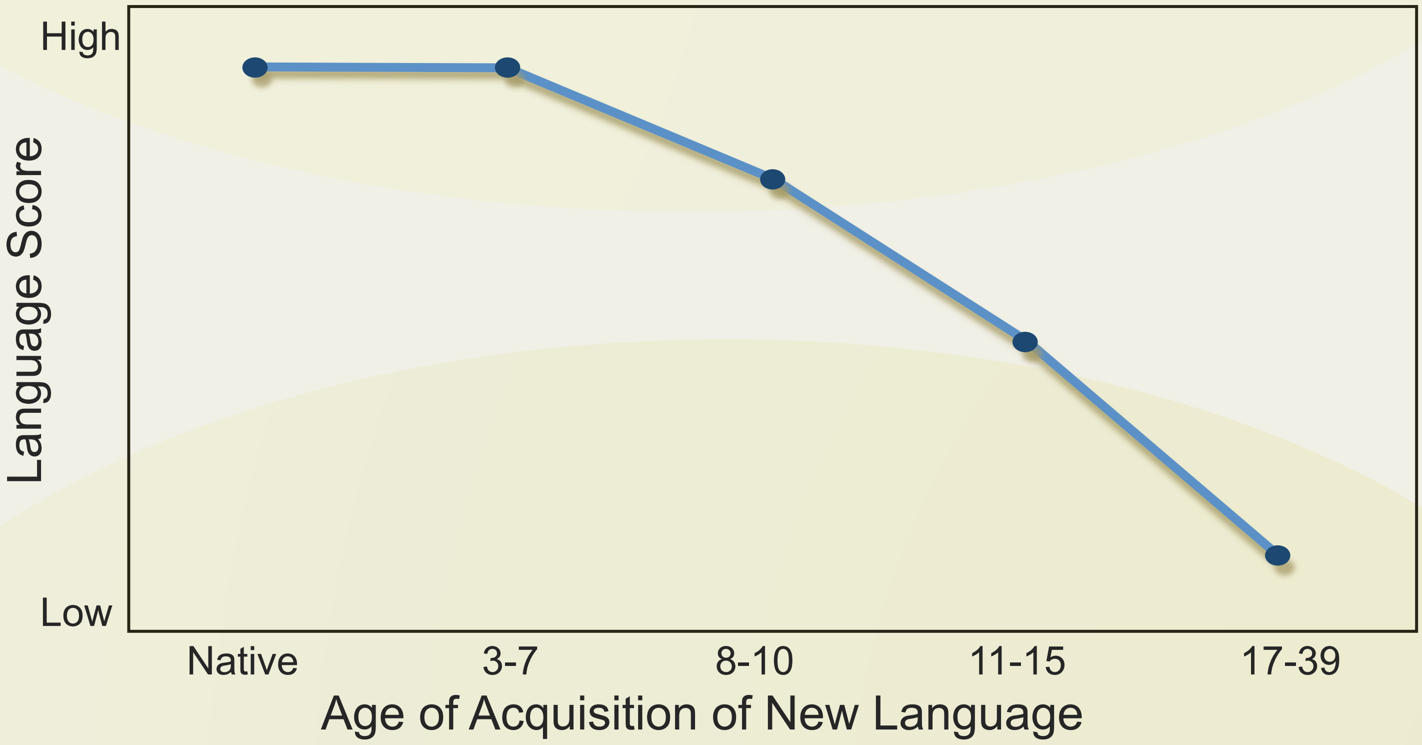
Brain Structure





Genes,
Brain &
Behavior

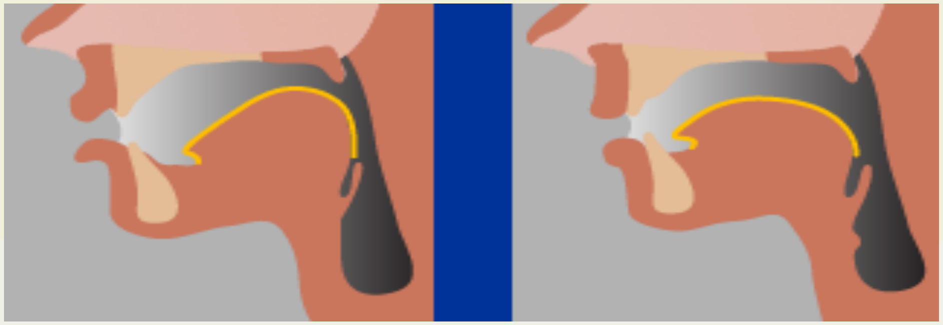
The ‘Critical Period’ for Language



Johnson & Newport, 1989

How Speech is Produced

/a/



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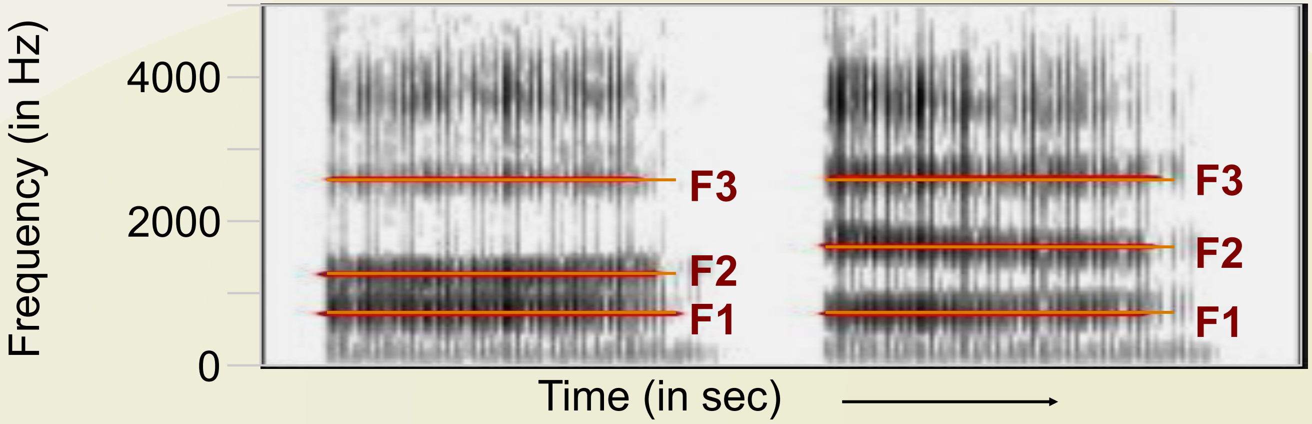
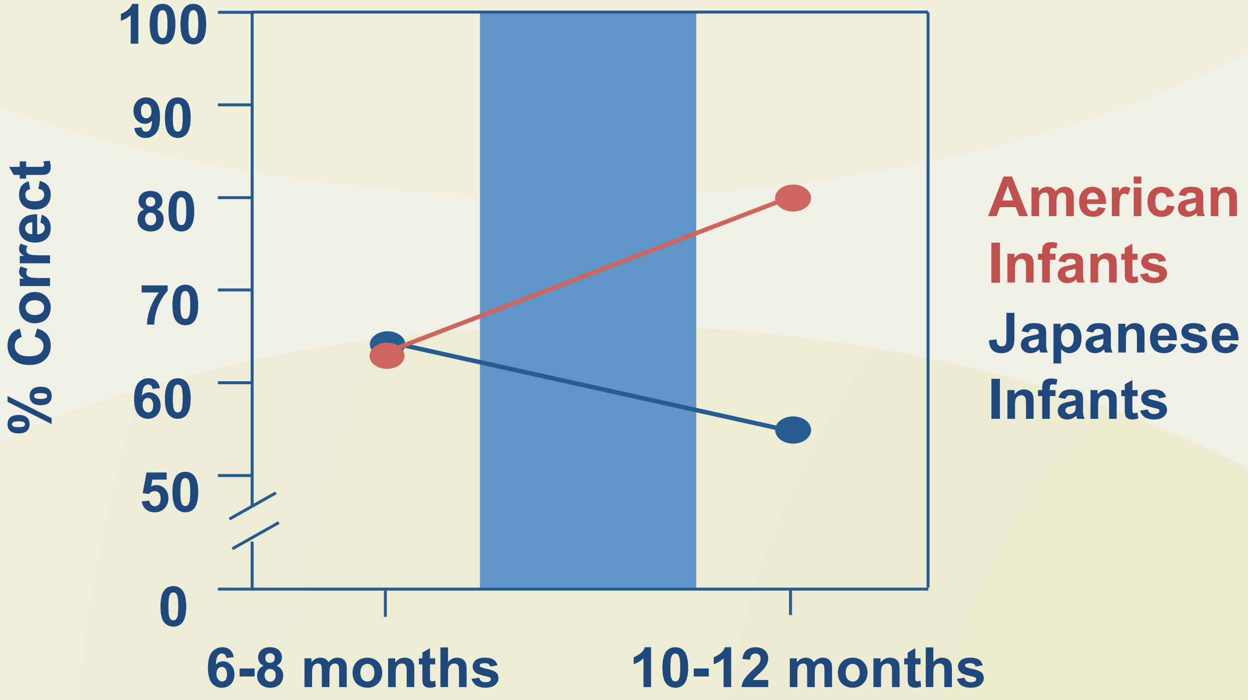
Physics of Sound



A ‘Sensitive Period’ for Speech Learning

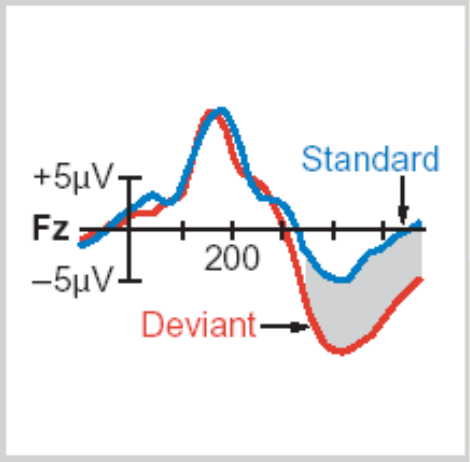
Infant discrimination of /ra/ vs. /la/



Kuhl et al., *Developmental Science*, 2006

Neural Signatures of Speech Learning

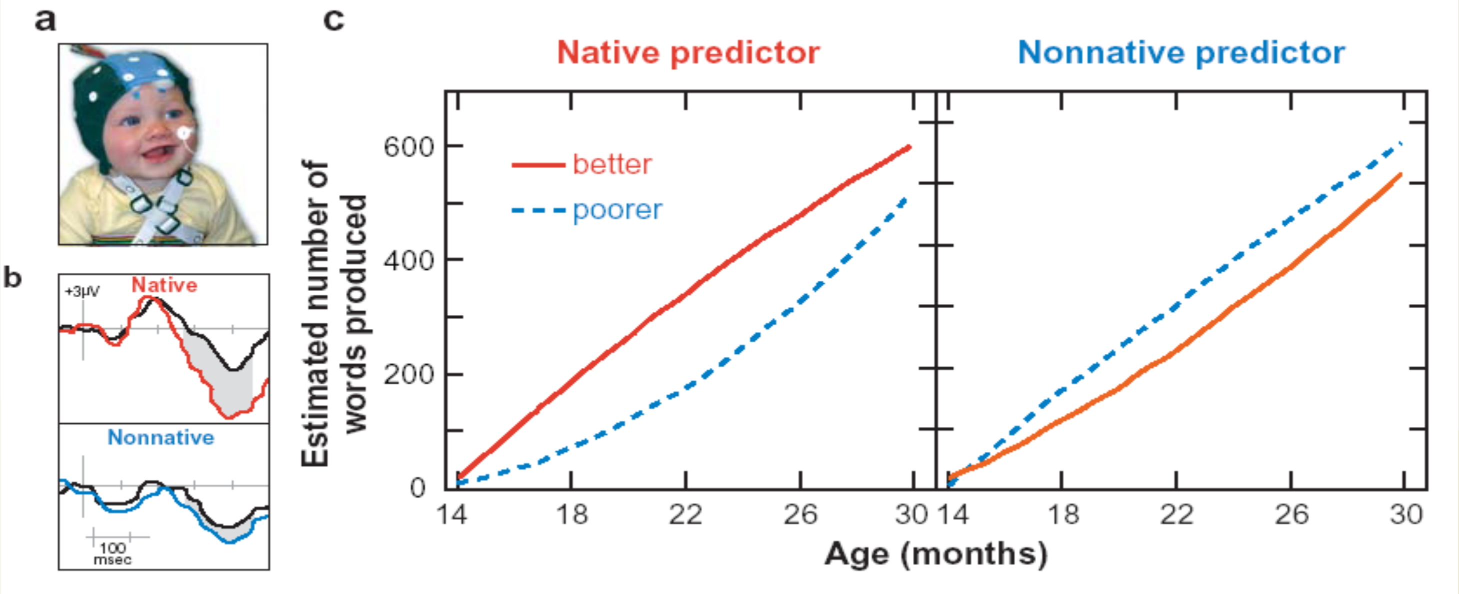
Event-related Potential (ERP): Mismatch Negativity



Mismatch Negativity (MMN)

Rivera-Gaxiola, Silva-Pereyra, & Kuhl, *Developmental Science,* 2005

ERPs to speech at 7.5 months predict language growth to 2.5 years of age

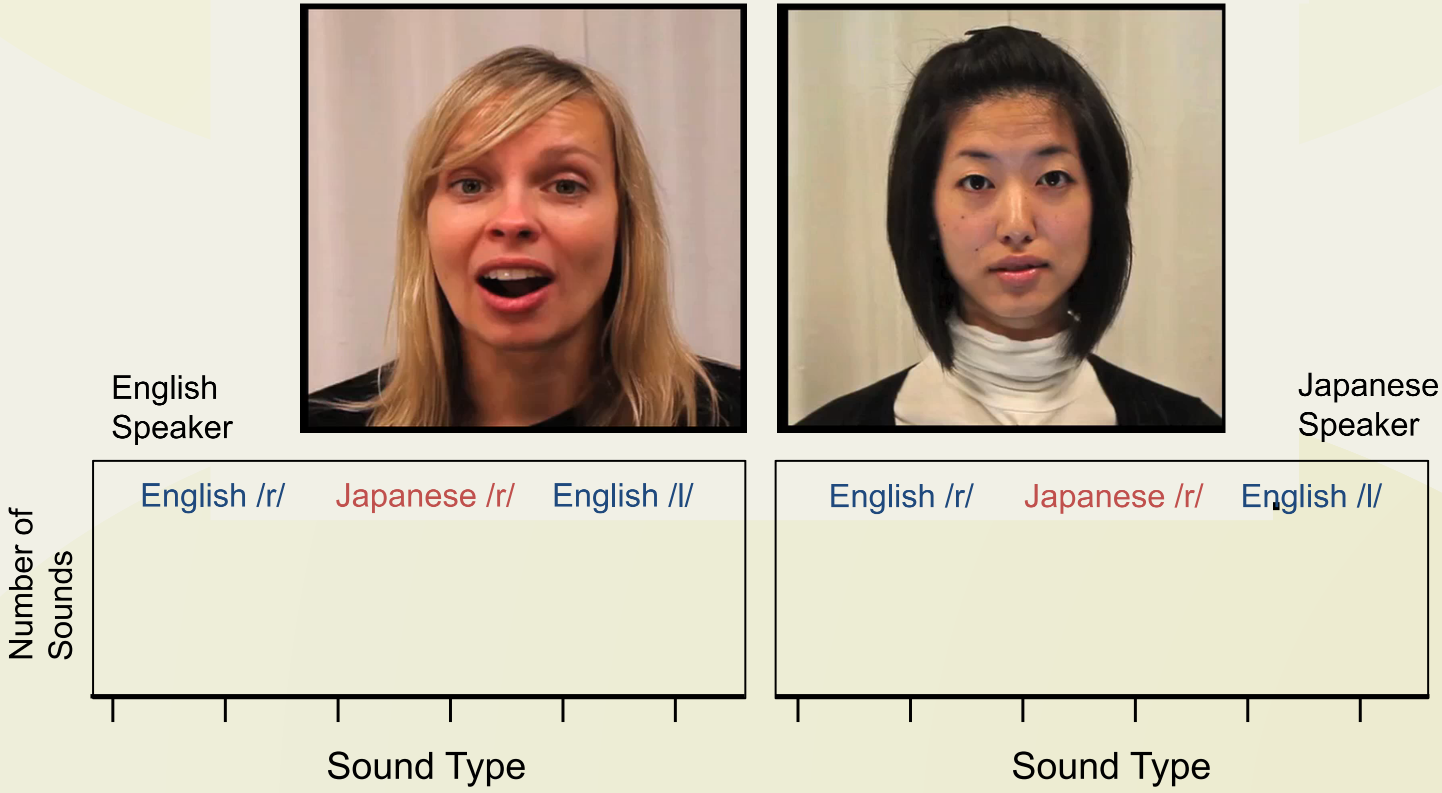


Kuhl et al., *Phil. Trans. of the Royal Society,* 2008

Powerful Learning Mechanisms

Statistical Learning + Social Learning

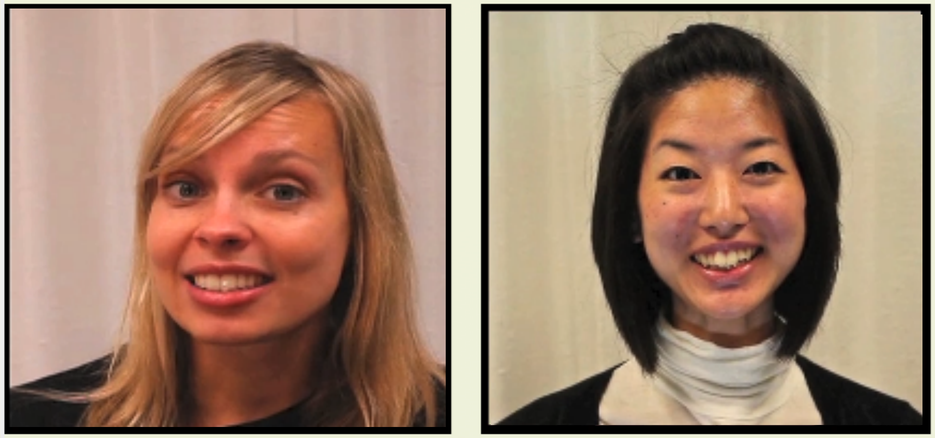
Statistics of “Parentese”



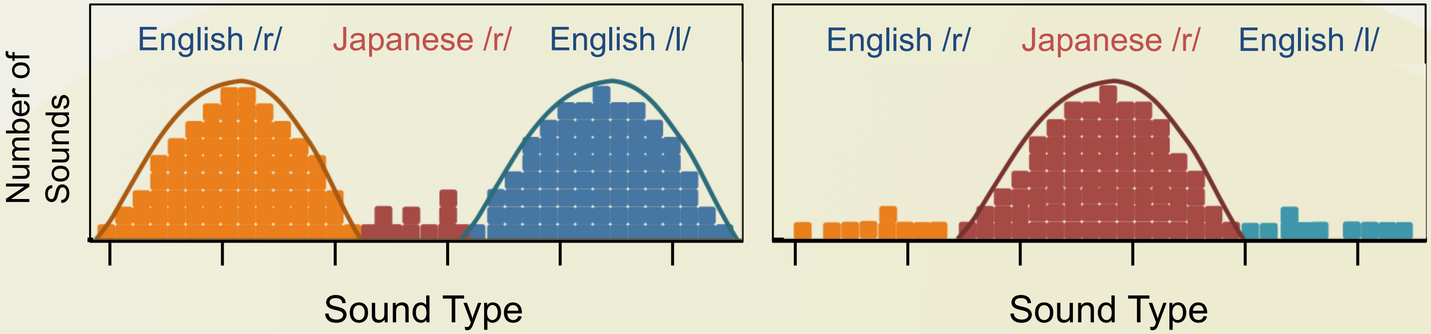
Kuhl et al., *Science*, 1992; TED.com, 2011

Statistics of "Parentese"

English
Speaker

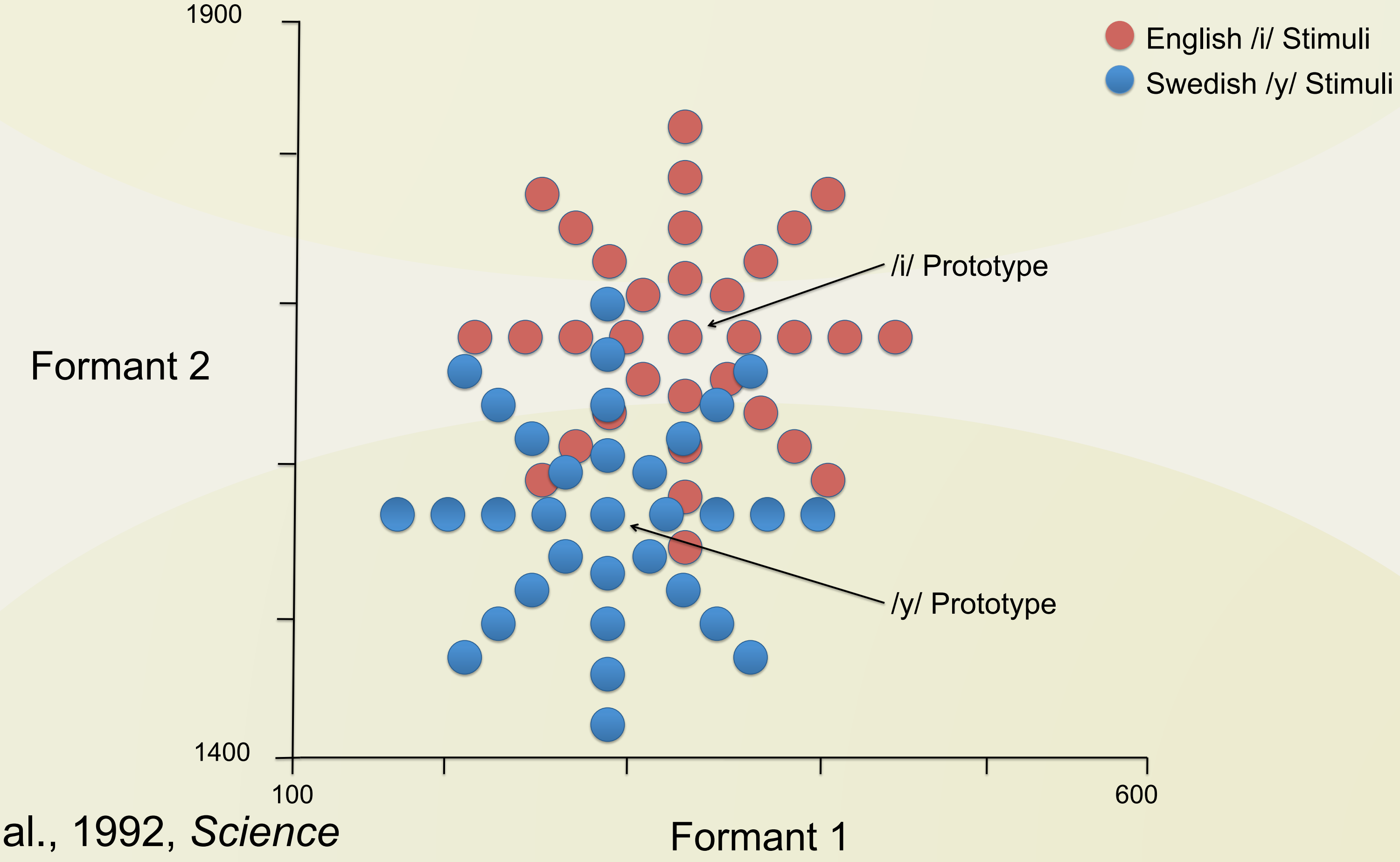


Japanese
Speaker



Kuhl et al., *Science*, 1992; TED.com, 2011

Infants' Sensitivity to Statistical Cues

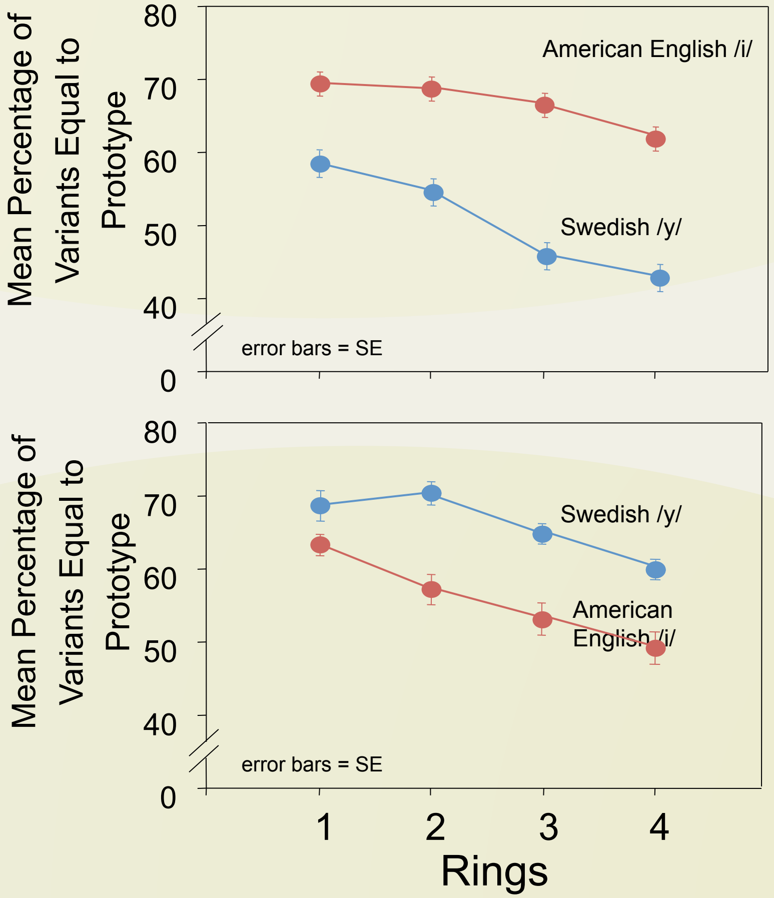


Kuhl et al., 1992, *Science*

Infants' Responses at 6 months of Age

American Infants

Swedish Infants



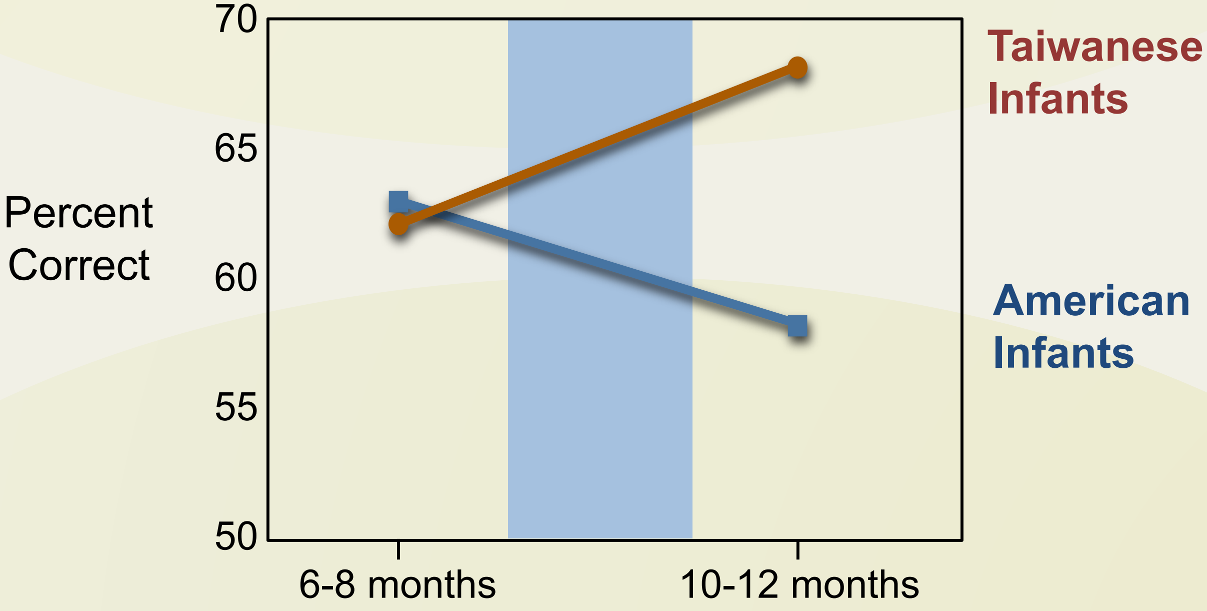
Kuhl et al., 1992, *Science*

New Question:

Can infants ‘take statistics’ on a new language during the sensitive period?

Perception of Mandarin Chinese Sounds

Intervention: 12 sessions, 25 minutes each,
4 different talkers (mean # of syllables = 33,000)



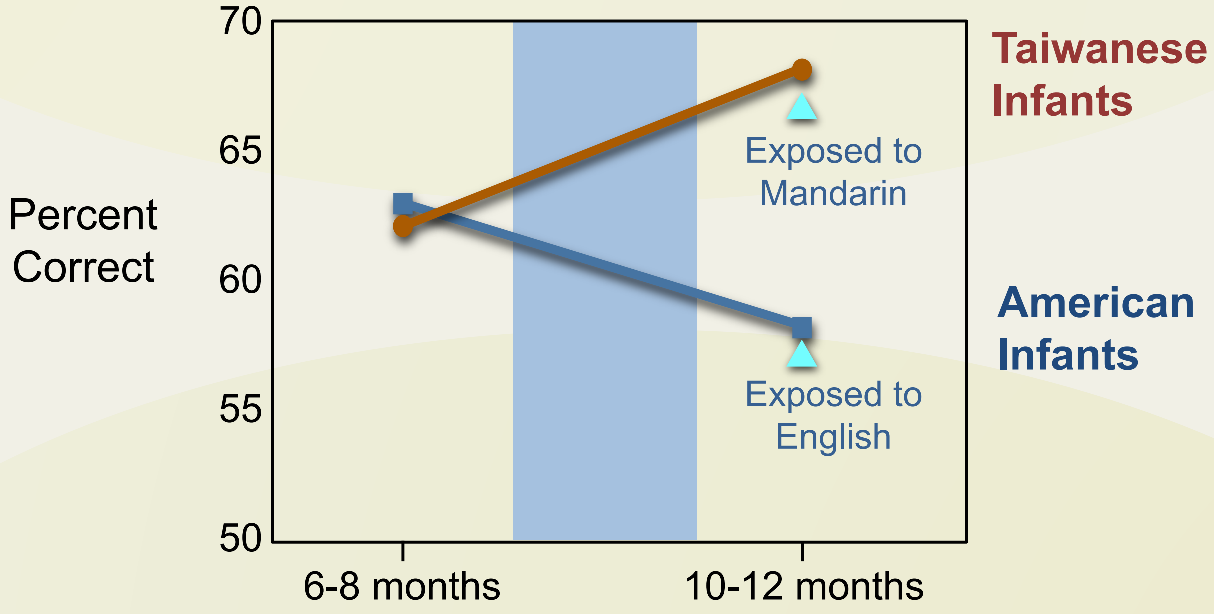
Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences*, 2003

Mandarin Chinese Exposure

12 sessions between 9 and 10.5 months of age

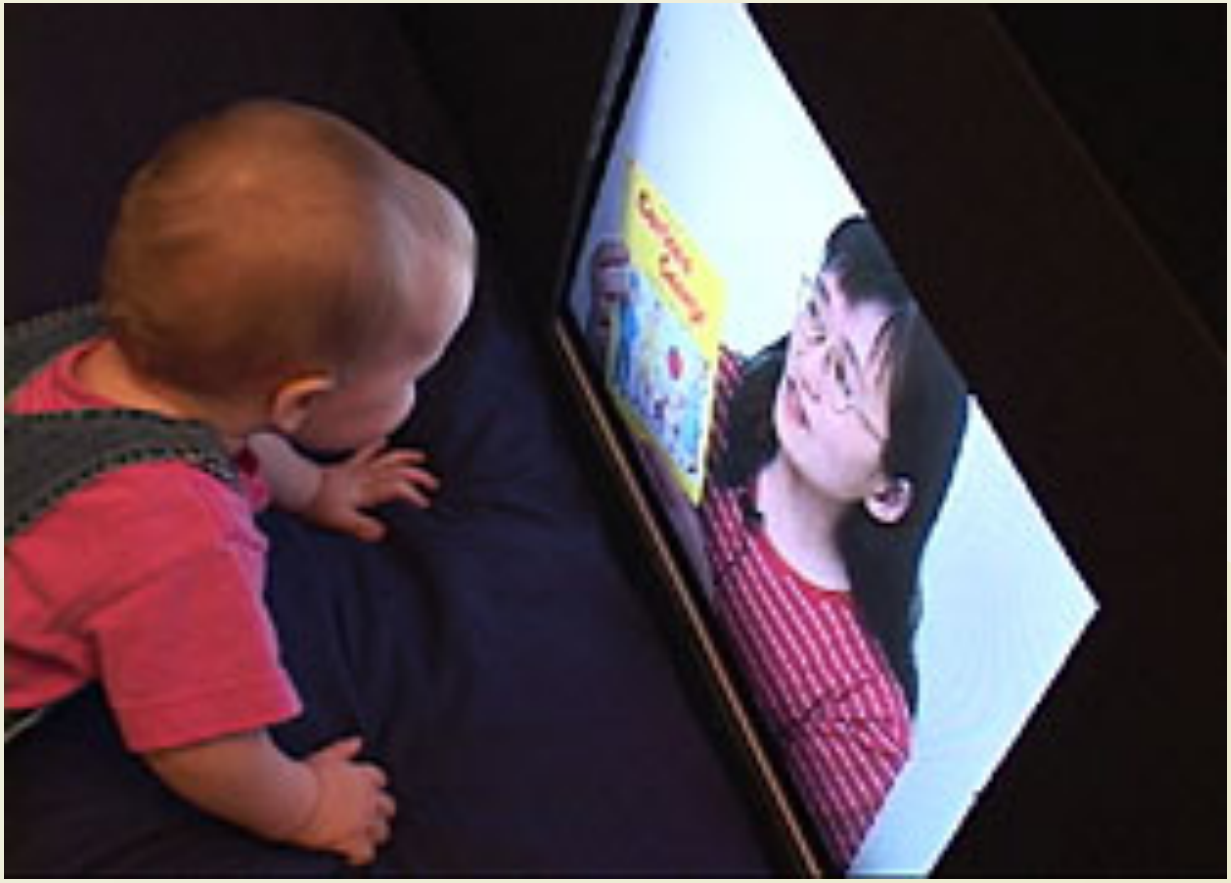
Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences*, 2003

Did Infants Learn?



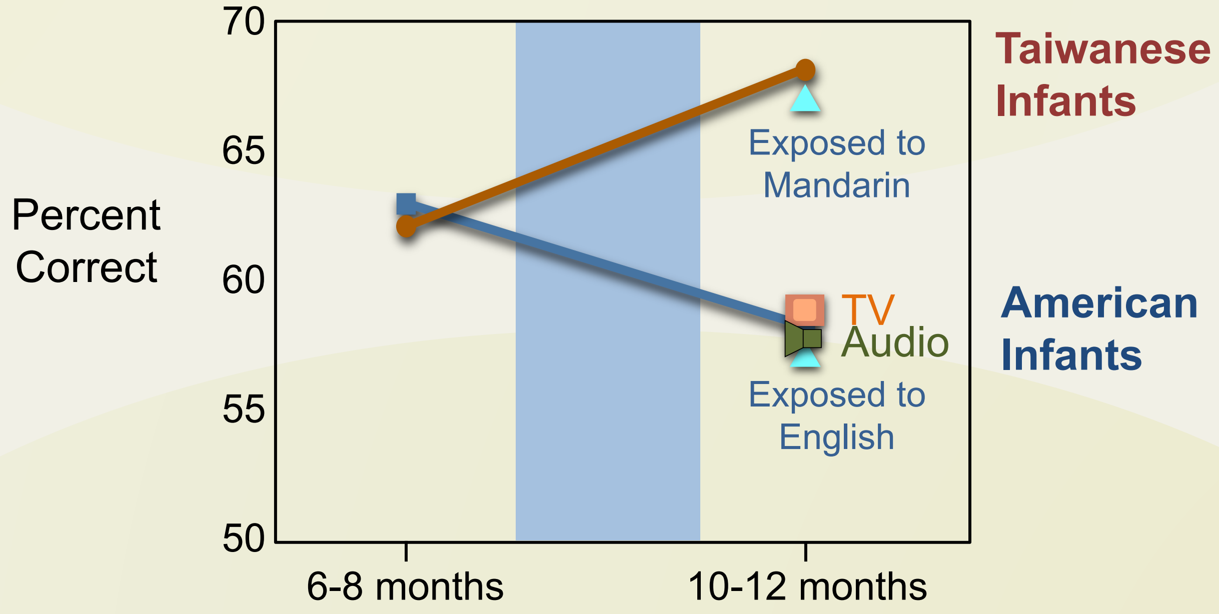
Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences*, 2003

Do Infants Learn From a Machine?



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences*, 2003

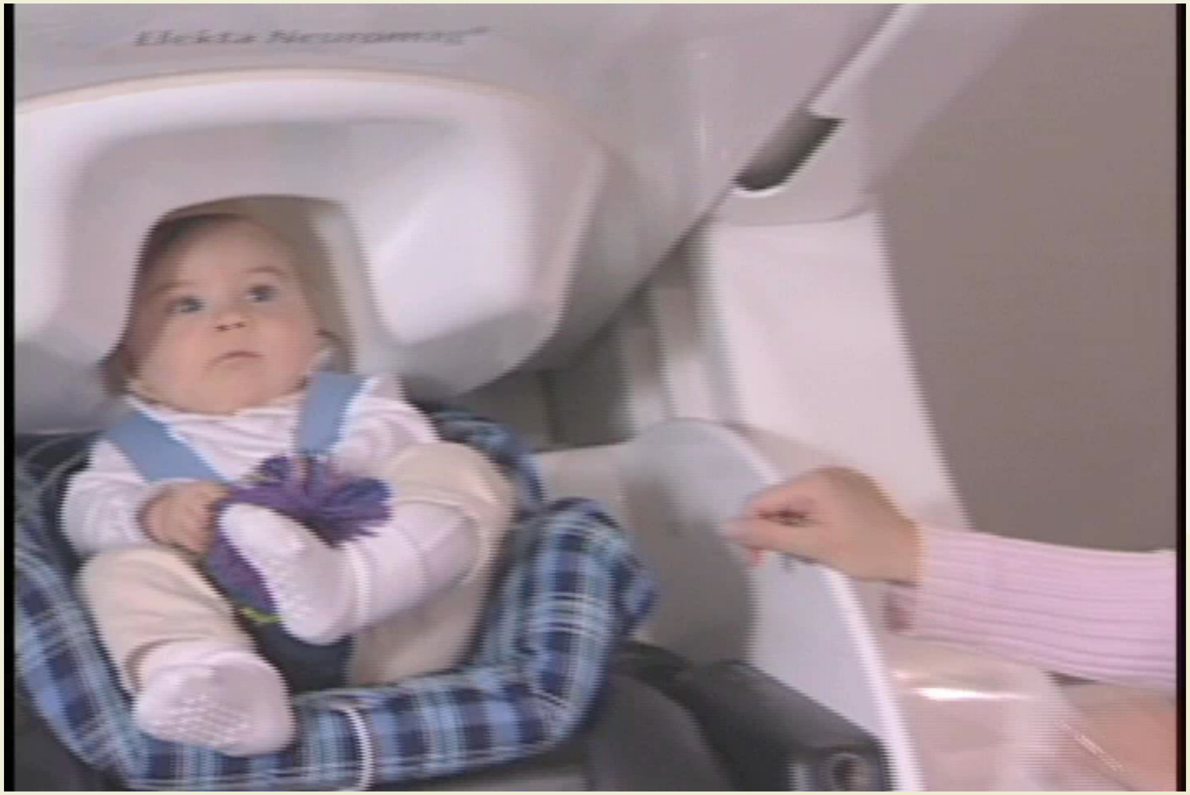
Do Infants Learn Language From Video?



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences*, 2003

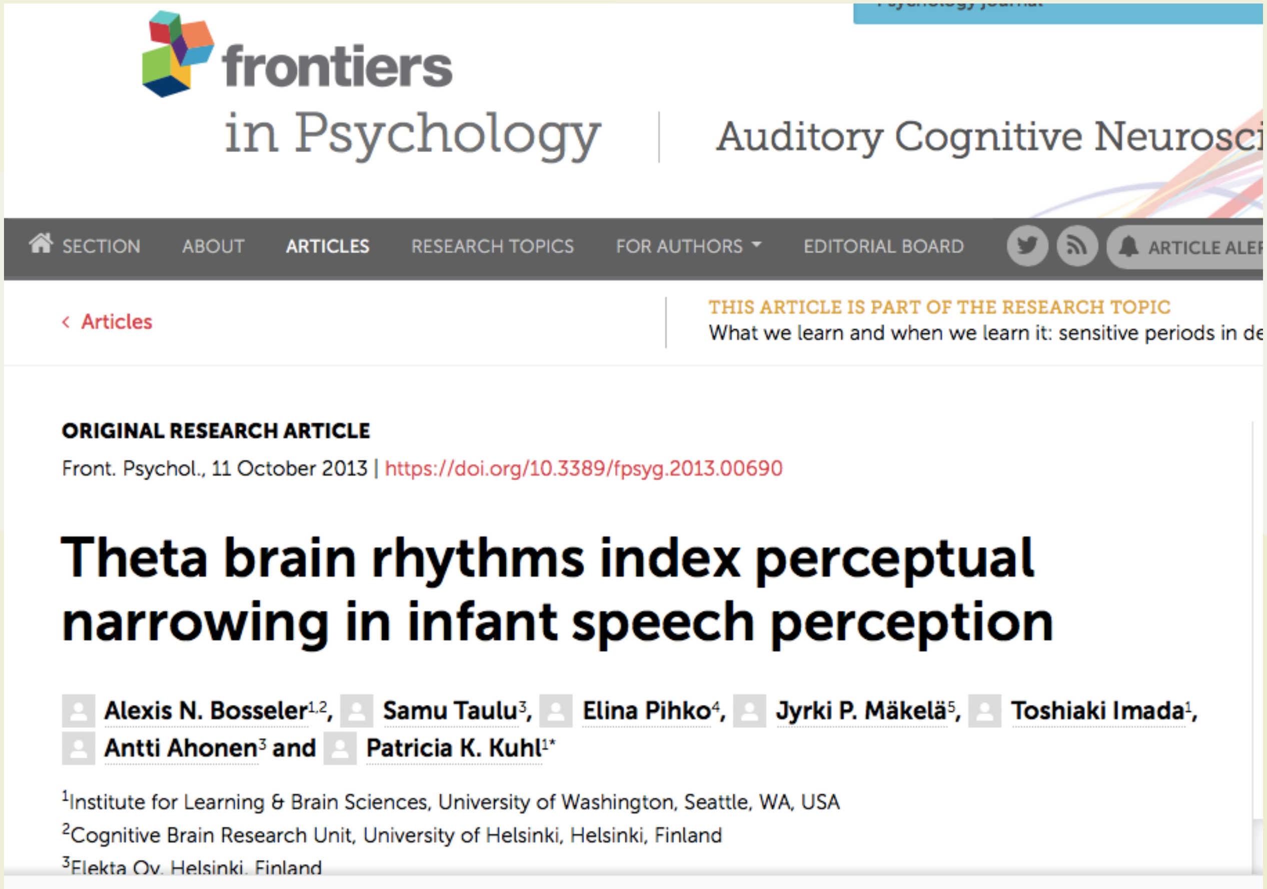
Magnetoencephalography (MEG)

Baby MEG



Imada, et al., *NeuroReport*, 2006; Kuhl, et al., *PNAS*, 2014

MEG Evidence of Statistical Learning



THIS ARTICLE IS PART OF THE RESEARCH TOPIC
What we learn and when we learn it: sensitive periods in de

ORIGINAL RESEARCH ARTICLE

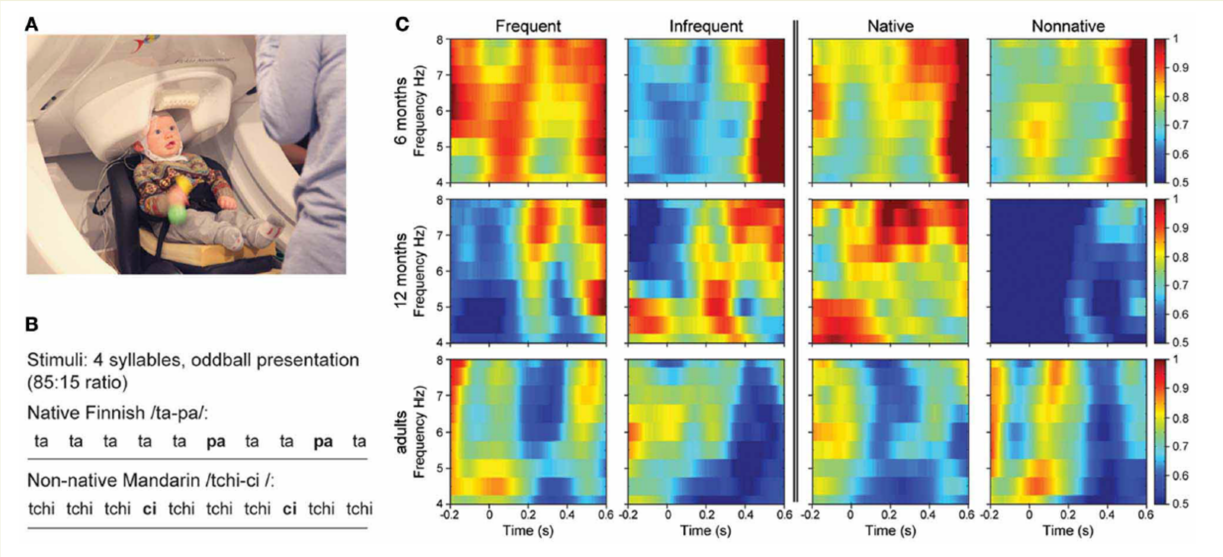
Front. Psychol., 11 October 2013 | https://doi.org/10.3389/fpsyg.2013.00690

Theta brain rhythms index perceptual narrowing in infant speech perception

Alexis N. Bosseler[1,2], **Samu Taulu**[3], **Elina Pihko**[4], **Jyrki P. Mäkelä**[5], **Toshiaki Imada**[1], **Antti Ahonen**[3] and **Patricia K. Kuhl**[1*]

[1]Institute for Learning & Brain Sciences, University of Washington, Seattle, WA, USA
[2]Cognitive Brain Research Unit, University of Helsinki, Helsinki, Finland
[3]Elekta Oy, Helsinki, Finland

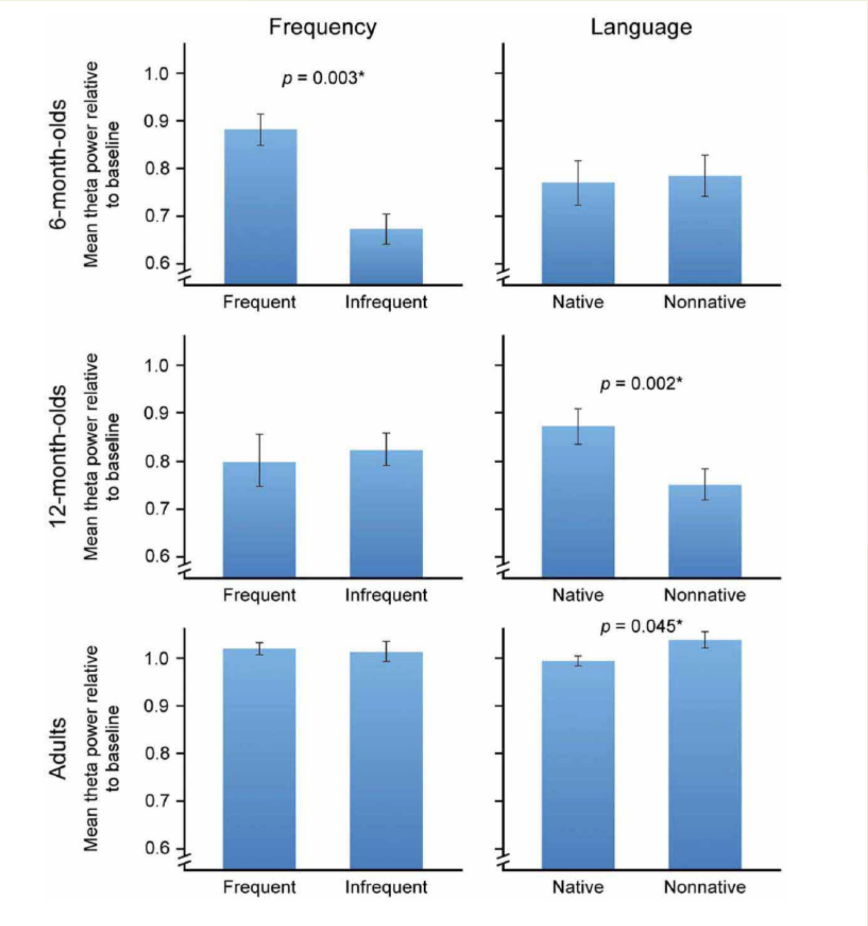
MEG Oscillatory Responses to Syllables: 6- and 12-Months vs. Adults



Bosseler, Taulu, Pihko, Makela, Imada, Ahonen & Kuhl,
Frontiers in Psychology, 2013

MEG Measures of Statistical Learning

- At 6 months of age, infants attend to the most frequent stimulus regardless of language.
- By 12 months, attention is drawn to the native stimulus regardless of frequency.
- In adults, attention and cognitive effort is increased by nonnative stimuli.



Bosseler, Taulu, Pihko, Makela, Imada, Ahonen & Kuhl, *Frontiers in Psychology,* 2013

MEG Evidence of Sensorimotor Interaction in Speech Learning

Infants' brain responses to speech suggest Analysis by Synthesis

Patricia K. Kuhl[1], Rey R. Ramírez, Alexis Bosseler, Jo-Fu Lotus Lin, and Toshiaki Imada

Institute for Learning and Brain Sciences, University of Washington, Seattle, WA 98195

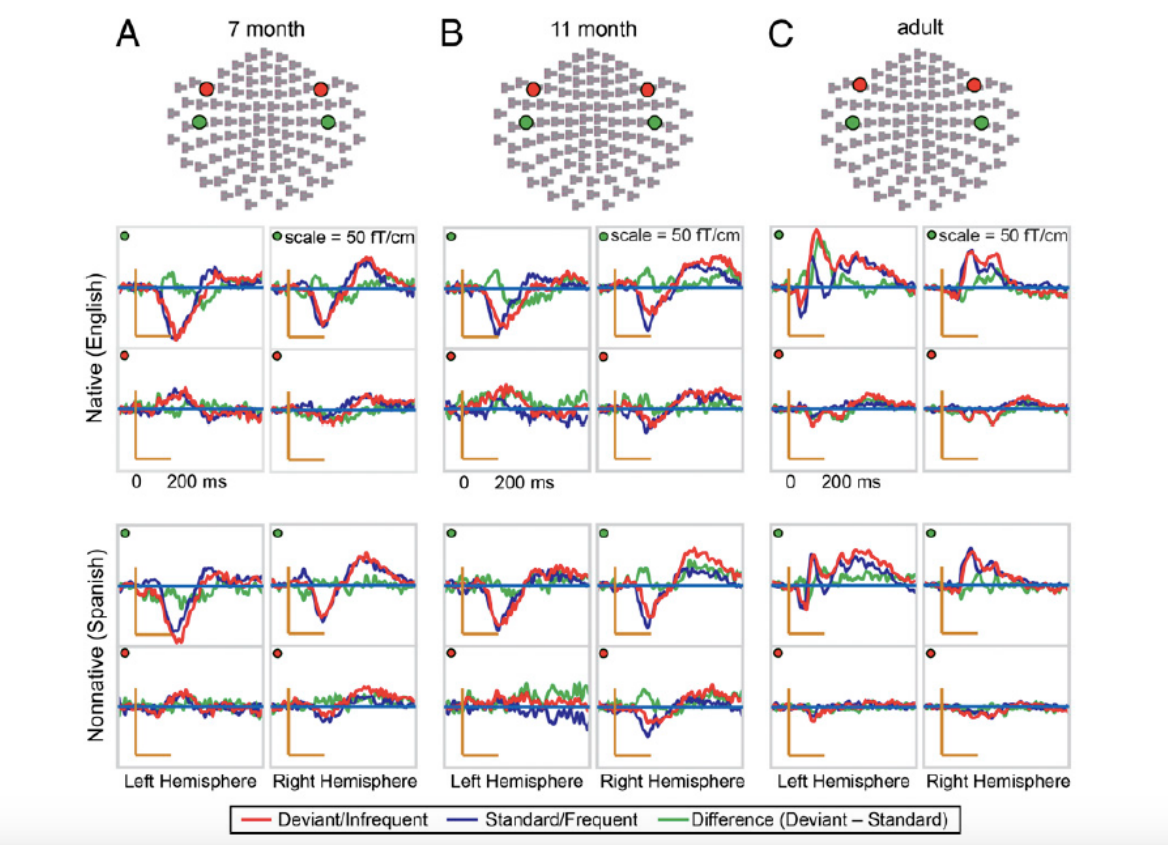
This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected in 2010.

Contributed by Patricia K. Kuhl, June 16, 2014 (sent for review January 30, 2014)

Historic theories of speech perception (Motor Theory and Analysis

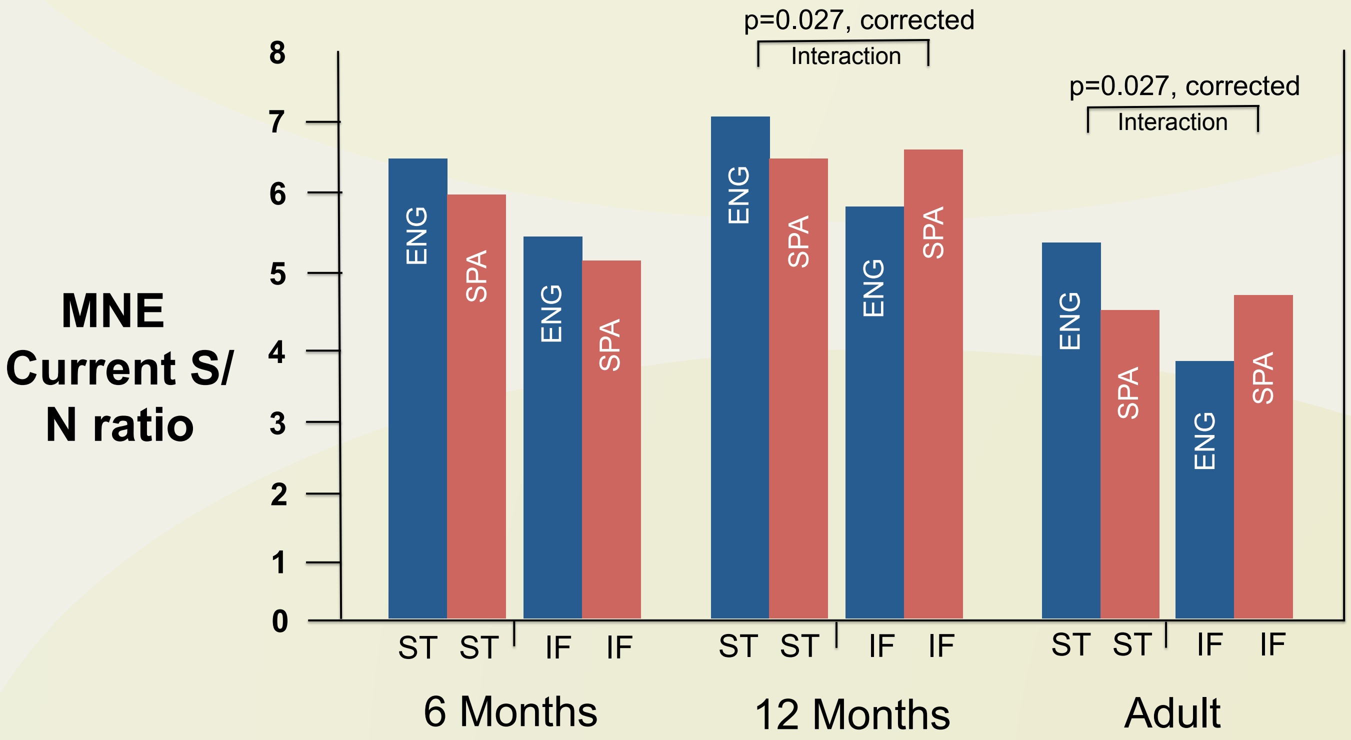
language at 9 mo in play sessions by a live tutor learn to dis-

Focus on Sensorimotor Activation



Kuhl et al. *PNAS*, 2014

MEG Results:
Interaction (Age, Language, Region)



Region

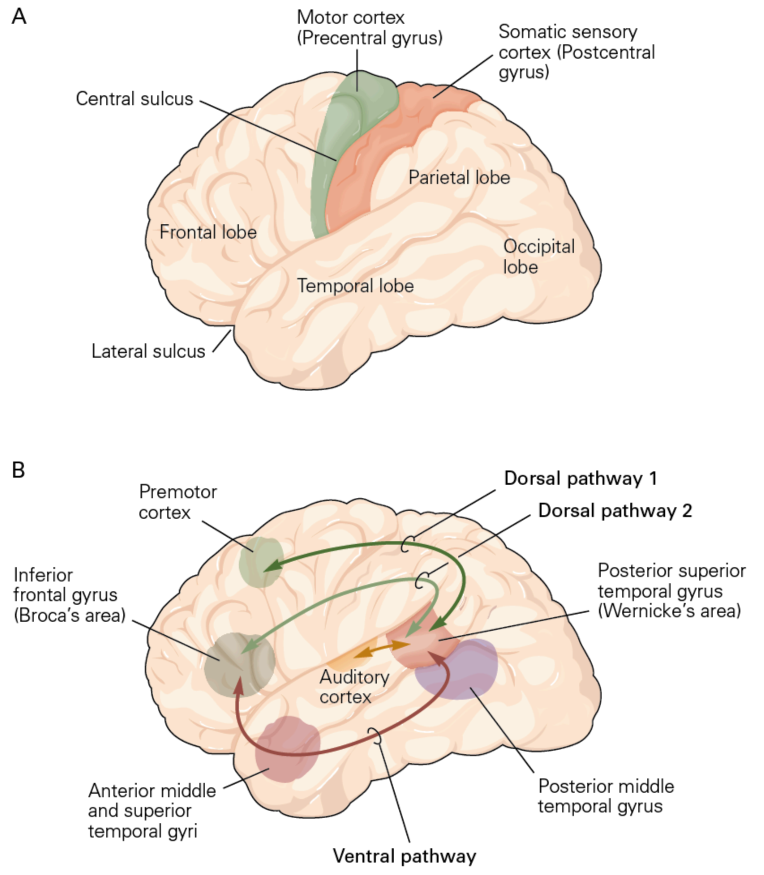
ST = Superior Temporal
IF = Inferior Frontal

Kuhl, Ramirez, Bosseler, Lin, & Imada *PNAS, 2014*

The Dual-Stream Network for Language

Dorsal Pathway: Sensorimotor stream

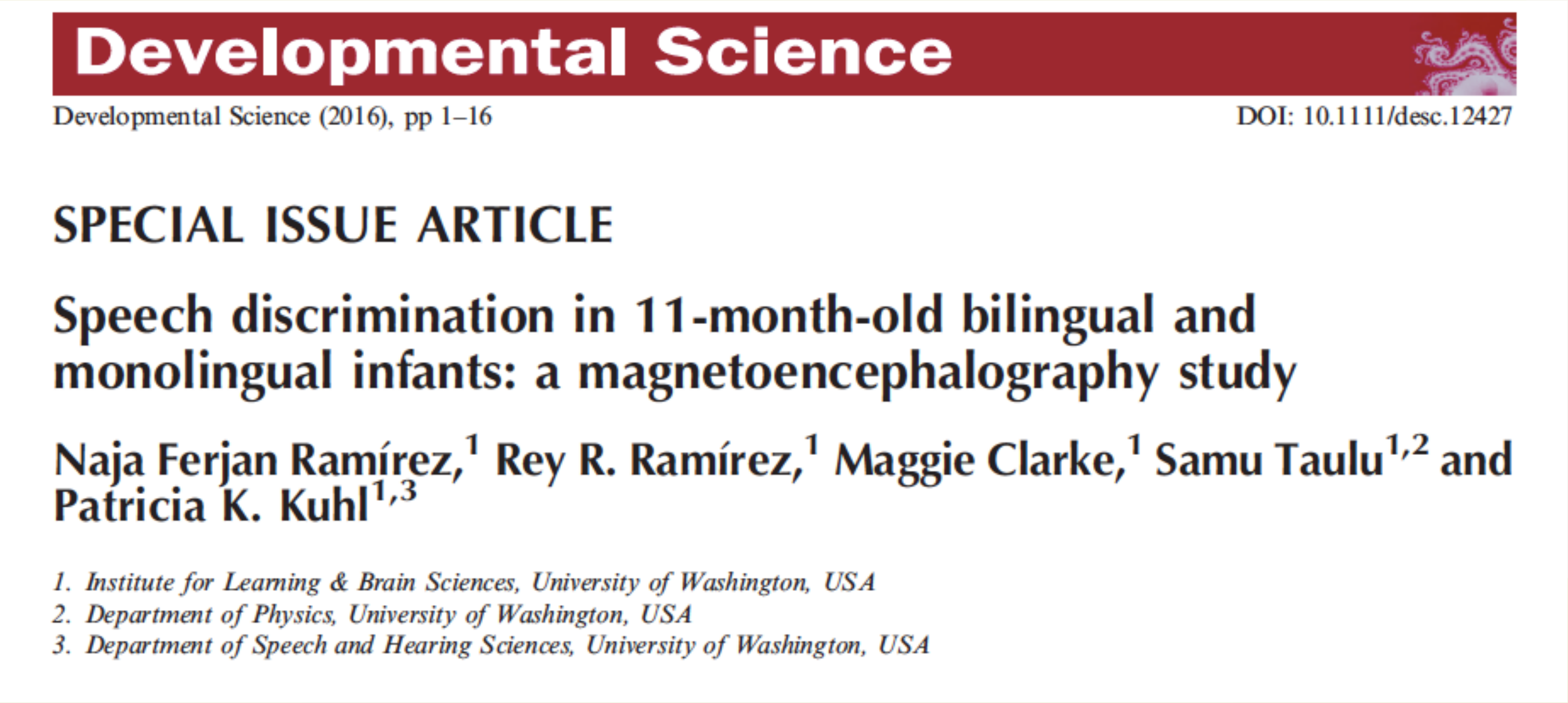
Ventral Pathway: Sound to meaning stream


A
Motor cortex (Precentral gyrus)
Somatic sensory cortex (Postcentral gyrus)
Central sulcus
Parietal lobe
Frontal lobe
Occipital lobe
Temporal lobe
Lateral sulcus
B
Premotor cortex
Dorsal pathway 1
Dorsal pathway 2
Inferior frontal gyrus (Broca's area)
Posterior superior temporal gyrus (Wernicke's area)
Auditory cortex
Anterior middle and superior temporal gyri
Posterior middle temporal gyrus
Ventral pathway

Kuhl, in Kandel et al. (Ed.), Principles of Neural Science, In press, 2018 (adapted from Hickok & Poeppel 2007; Skeide & Friederici 2016)

Bilingual and Monolingual Babies Tested in MEG at 11 Months

Bilingual and Monolingual Speech Processing at 11 Months



Developmental Science

Developmental Science (2016), pp 1–16 DOI: 10.1111/desc.12427

SPECIAL ISSUE ARTICLE

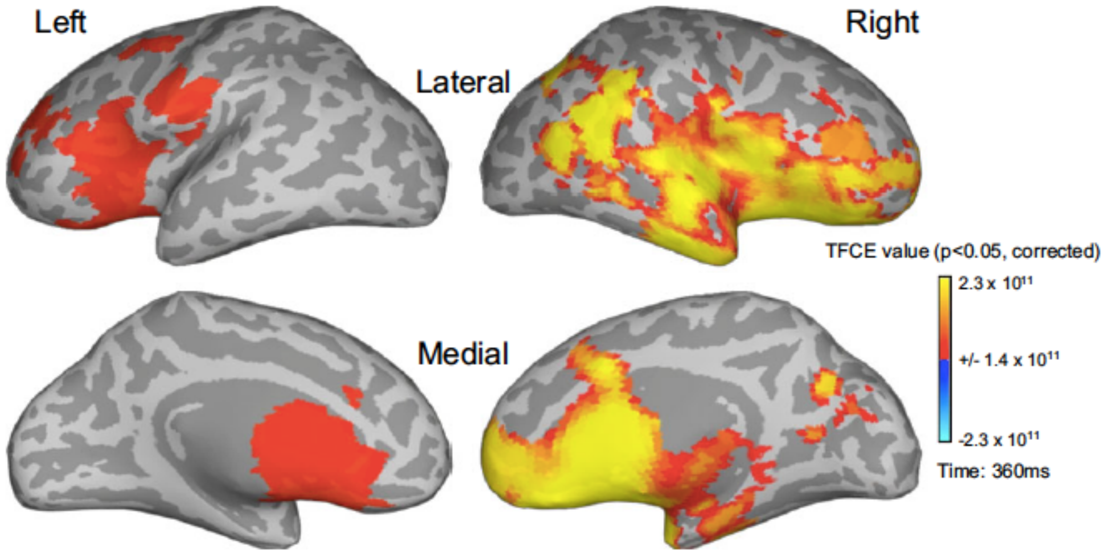
Speech discrimination in 11-month-old bilingual and monolingual infants: a magnetoencephalography study

Naja Ferjan Ramírez,[1] Rey R. Ramírez,[1] Maggie Clarke,[1] Samu Taulu[1,2] and Patricia K. Kuhl[1,3]

1. *Institute for Learning & Brain Sciences, University of Washington, USA*
2. *Department of Physics, University of Washington, USA*
3. *Department of Speech and Hearing Sciences, University of Washington, USA*

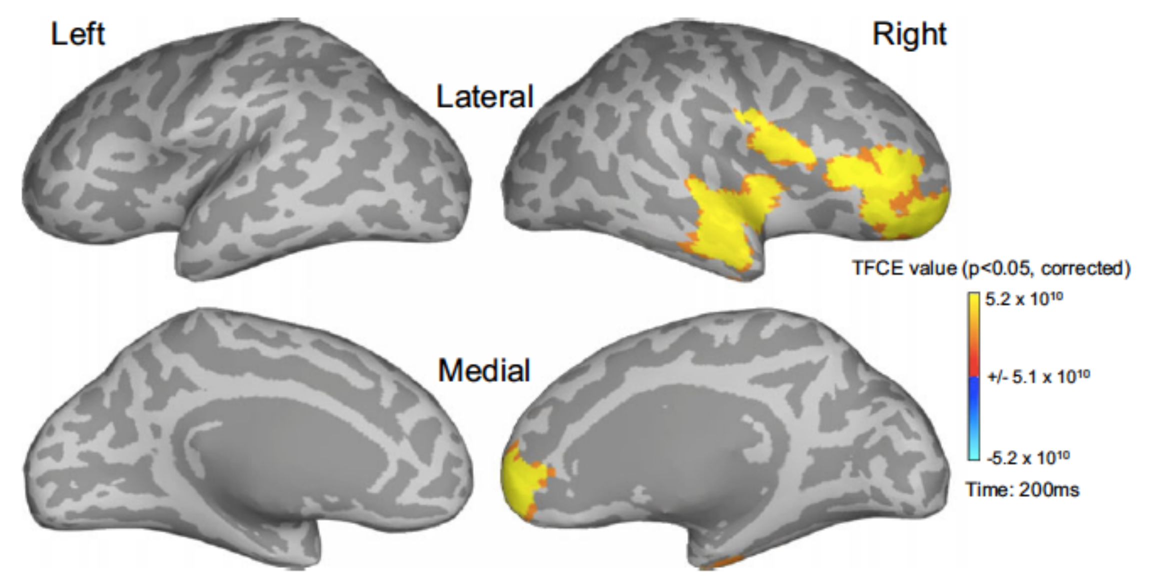
***Naja Ferjan Ramirez: Developmental Science* Early Career Research Prize, 2016**

Monolingual Infants Show Significant Difference Between English and Spanish



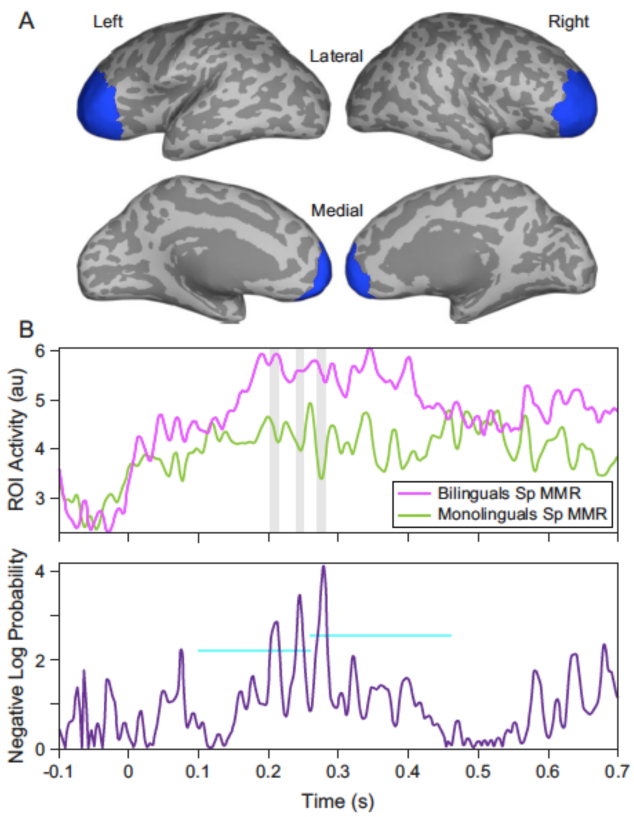
Ferjan-Ramirez, Ramirez, Clarke, Taulu, & Kuhl, 2017, *Developmental Science*

Bilingual Infants at 11 Months Show Greater Activation for Spanish



Ferjan-Ramirez, Ramirez, Clarke, Taulu, & Kuhl, 2017, *Developmental Science*

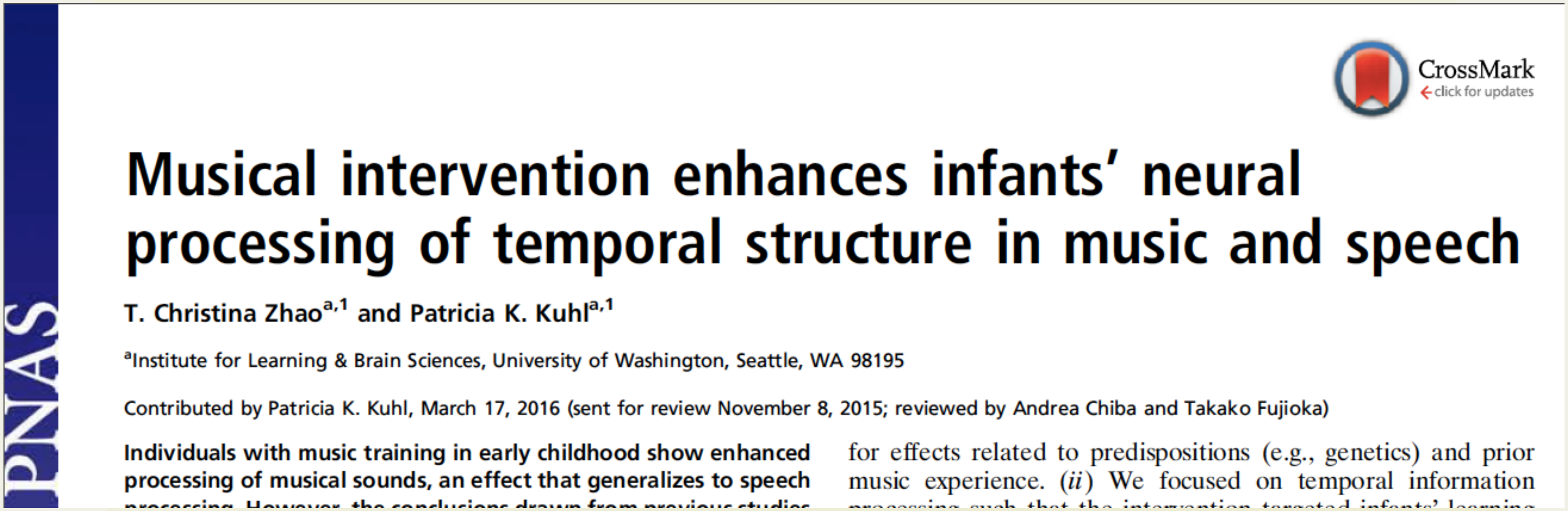
Bilingual Infants Show Greater Prefrontal Activation



Ferjan-Ramirez, Ramirez, Clarke, Taulu, & Kuhl, 2017, *Developmental Science*

MEG Shows Effects of Music on the Brain

Music Exposure Affects Speech


PNAS
CrossMark
click for updates

Musical intervention enhances infants' neural processing of temporal structure in music and speech

T. Christina Zhao[a,1] and Patricia K. Kuhl[a,1]

[a]Institute for Learning & Brain Sciences, University of Washington, Seattle, WA 98195

Contributed by Patricia K. Kuhl, March 17, 2016 (sent for review November 8, 2015; reviewed by Andrea Chiba and Takako Fujioka)

Individuals with music training in early childhood show enhanced processing of musical sounds, an effect that generalizes to speech

for effects related to predispositions (e.g., genetics) and prior music experience. (*ii*) We focused on temporal information

Music Intervention Affects the Brain

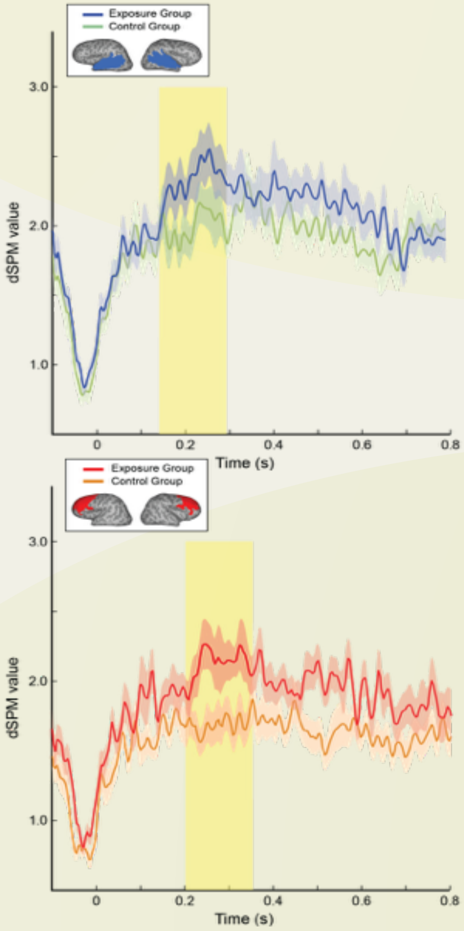
- The “waltz”
- Social environment
- 12 sessions over one month’s time
- Brain tests after exposure
- Track language development until 30 month of age

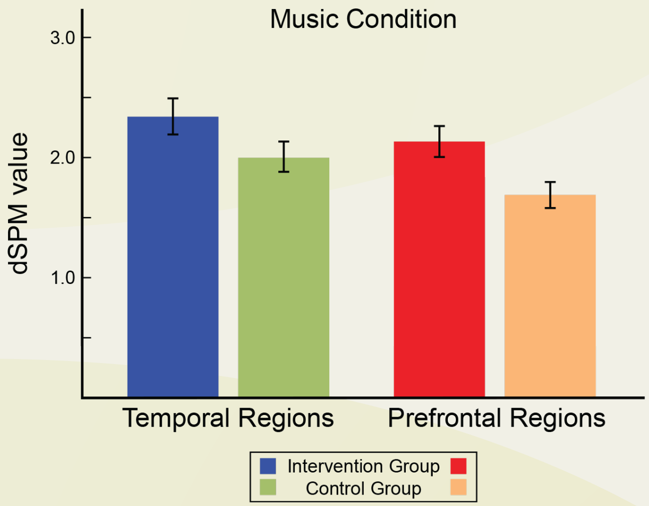
Zhao & Kuhl, *Proceedings of the National Academy of Sciences*, 2016

MEG Tests of Rhythmic Processing for Music and Speech

Zhao & Kuhl, *Proceedings of the National Academy of Sciences*, 2016

MEG Results for Music Test

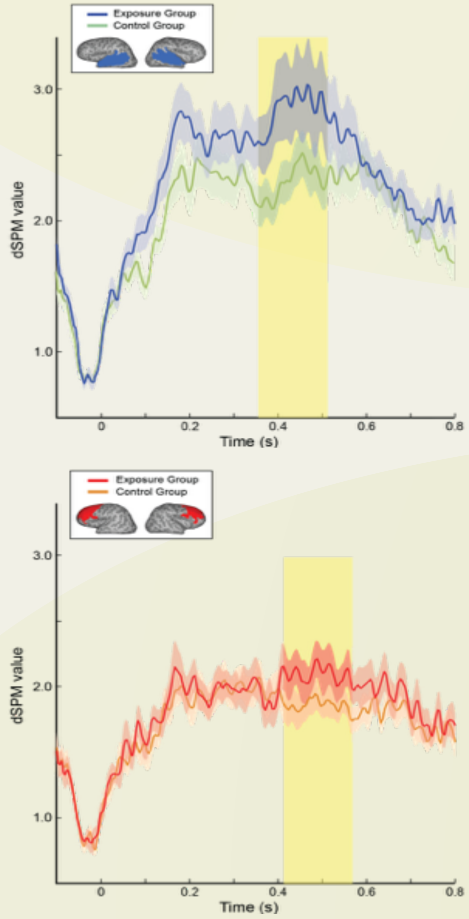


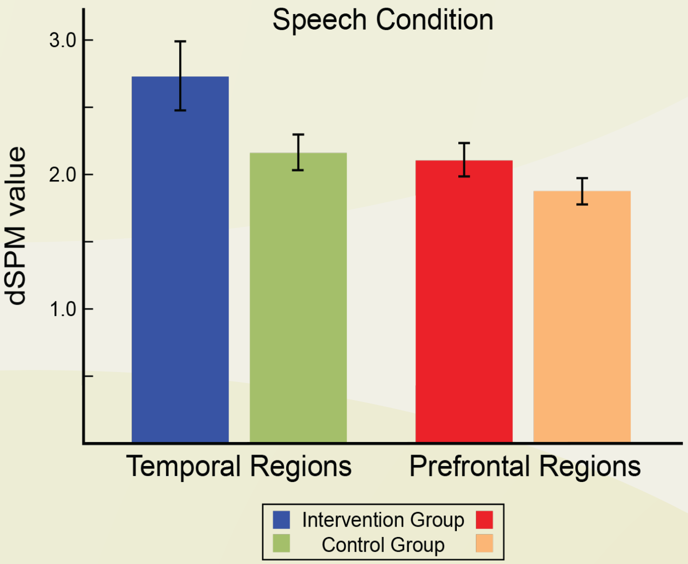


Significant differences in both Auditory and Prefrontal Cortex for detection of violations in musical rhythm, with the Intervention group showing stronger responses ($p < .01$).

Zhao & Kuhl, *PNAS*, 2016

MEG Results for Speech Test

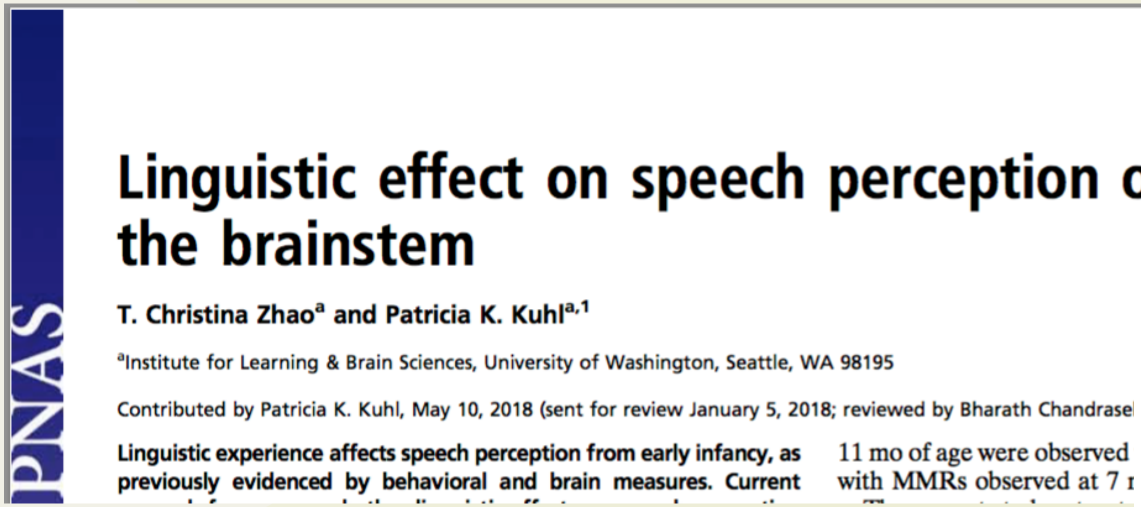




Significant differences in both Auditory and Prefrontal Cortex for detection of violations in speech rhythm, with the Intervention group showing stronger responses (*p* < .03).

Zhao & Kuhl, *PNAS*, 2016

Experience Affects Brainstem Responses to Speech



PNAS

Check for updates

Linguistic effect on speech perception observed at the brainstem

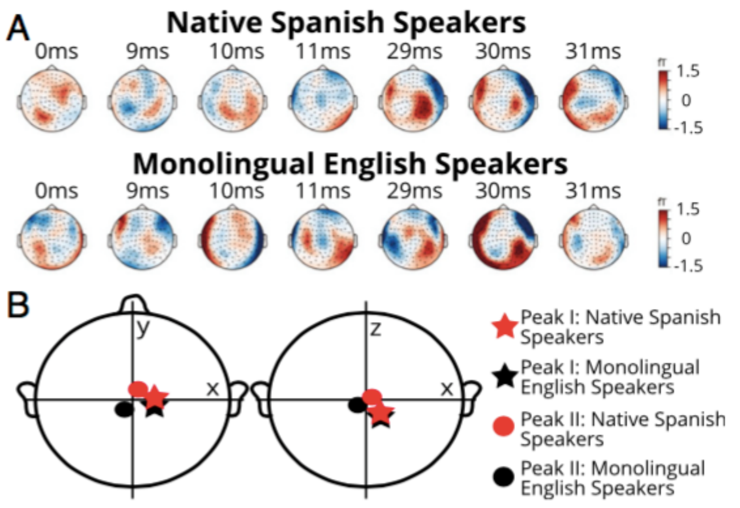
T. Christina Zhao[a] and Patricia K. Kuhl[a,1]

[a]Institute for Learning & Brain Sciences, University of Washington, Seattle, WA 98195

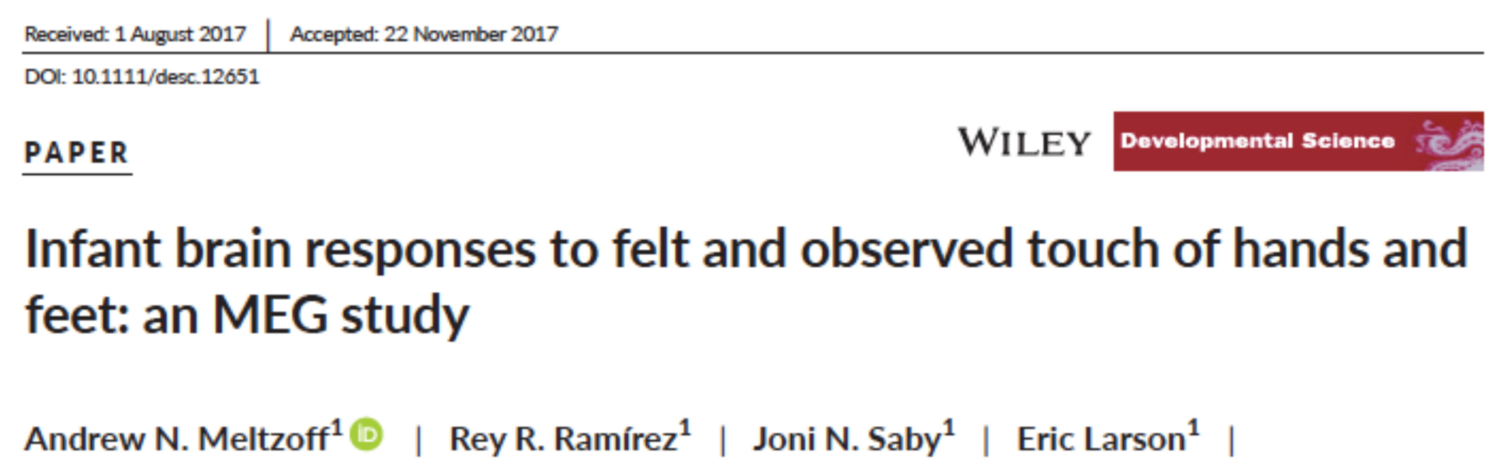
Contributed by Patricia K. Kuhl, May 10, 2018 (sent for review January 5, 2018; reviewed by Bharath Chandrase

Linguistic experience affects speech perception from early infancy, as previously evidenced by behavioral and brain measures. Current

11 mo of age were observed with MMRs observed at 7



MEG: Somotosensory Responses to Touch in Infancy



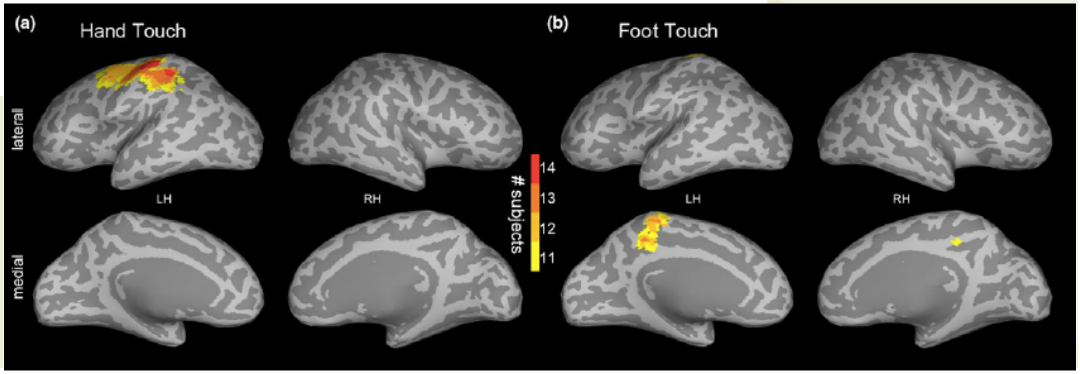
Received: 1 August 2017 | Accepted: 22 November 2017
DOI: 10.1111/desc.12651

PAPER

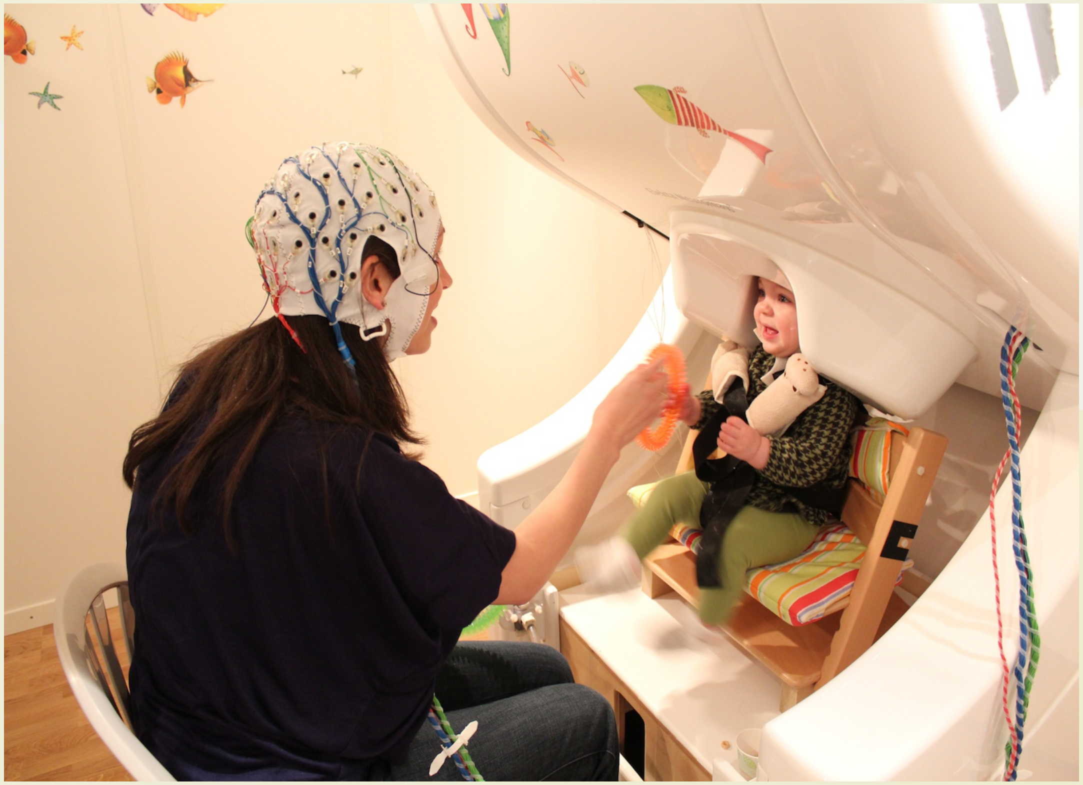
WILEY Developmental Science

Infant brain responses to felt and observed touch of hands and feet: an MEG study

Andrew N. Meltzoff[1] | Rey R. Ramírez[1] | Joni N. Saby[1] | Eric Larson[1] | Samu Taulu[1,2] | Peter J. Marshall[3]

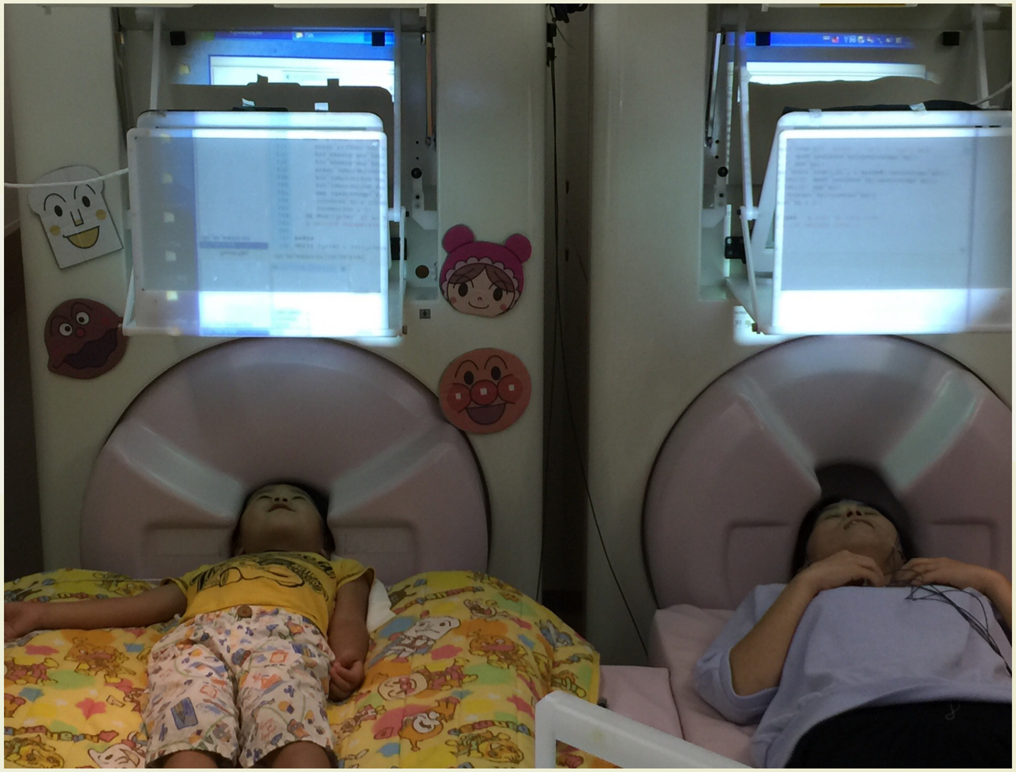


Co-Registration of Brain Activity: Face-to-Face Interaction



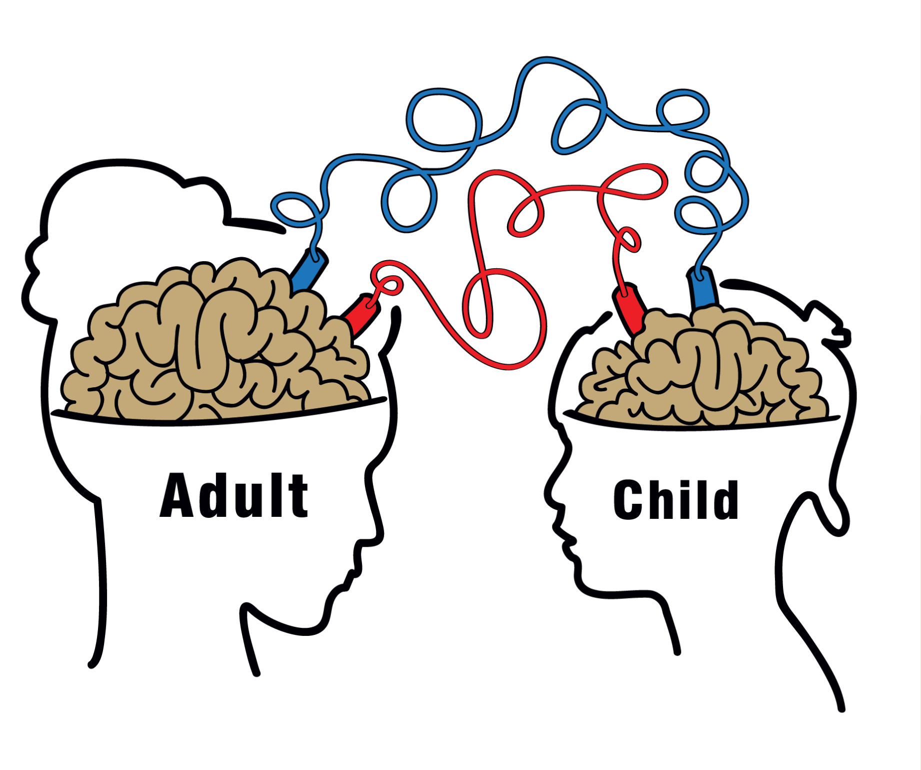
Bosseler et al.,
Work in progress

MEG Hyperscanning: Mothers and 5-yr-olds



BioMag: W-116, Brain to Brain Synchronization During Mother-Child Interaction
Jo-Fu Lotus Lin et al., 2018

Future: Portable and Affordable Ways to Measure Human Learning



Kuhl Lab Group & Collaborators

Predicting Language

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- Feng-Ming Tsao
- Lindsay Klarman

Social & Language/ Technology Studies

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- Andrew Meltzoff
- Sarah Roseberry Lytle
- Javier Movellan

Newborn Studies

- Christine Moon
- Hugo Lagercrantz

Animal Studies

- Jim Miller

Parentese Studies

- Anne Fernald
- Huei-Mei Liu
- Nairan Esparza Ramirez

ERP Studies

- Adrian Garcia Sierra
- Barbara Conboy
- Sharon Coffey-Corina
- Maritza Rivera-Gaxiola
- Juan Silva-Pereyra

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- Denise Padden
- Sharon Coffey-Corina
- Geri Dawson
- Cheri Percaccio
- Kambiz Tavabi

Music Studies

- Christina Zhao

Genetic Studies

- Ping Mamiya
- Evan Eichler

Reading Readiness

- Jason Yeatman
- Maria Mittag

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- Ken Stevens
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- Yoh'ichi Tohkura

Bilingual/LENA Project

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- Nairan Ramirez-Esparza
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- Harriett Romo

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- Nairan Ramirez-Esparza

Parent Coaching

- Nairan Ramirez-Esparza
- Sarah Roseberry Lytle

MRI/ DTI Studies

- Todd Richards
- Neva Corrigan
- Raj Raizada
- Jeff Stevenson
- Lisa Akiyama
- Jasper van den Bosch

Kuhl Laboratory Supporters

- The Bezos Family Foundation
- The Gates Foundation
- NSF Science of Learning Center grant
- The National Institutes of Health
- The Simms-Mann Foundation
- The Kaiser Foundation
- The Overdeck Foundation
- Robert Wood Johnson Foundation
- WA State Life Sciences Fund

Thank You!

Thank You!

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